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Frequency measurements in microwave spectroscopy

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With 1 figure in the text

Accurate measurements of line frequencies in microwave spectroscopy are usually made by reference to a series of equidistant standard frequencies covering the microwave region in question. These standard frequencies are produced as harmonics of a radio frequency generated by a quartz crystal oscillator.

The difference between the line frequency and one of the standard frequencies is usually measured by means of a calibrated communications receiver. The line frequency is then:

$$\nu = n\nu_0 \pm \Delta\nu,$$

where ν_0 is the fundamental standard frequency, n is an integer and $\Delta\nu$ is the measured difference. The sign of $\Delta\nu$ is easily determined by varying the receiver setting. The determination of n requires one more measurement. The usual procedure is to make a coarse measurement of ν with a cavity wavemeter. The accuracy of this measurement must evidently be better than $\pm\nu_0/2$ to make the value of n unambiguous.

In the spectrometer described by one of us [1] the spacing between the standard frequencies is 10 MHz. For unambiguous identification of one of these the coarse measurements must be reliable to better than ± 5 MHz. Since the cavity wavemeters employed do not always yield this accuracy, it has often been necessary to check the results by reference to neighbouring lines of known frequency. Ways of improvement of the situation has therefore been sought for.

A larger spacing between the standard frequencies would, of course, make the identification easier but would also increase the requirements on the interpolation receiver. The close spacing is also very convenient for the adjustment of the microwave system. The advantage is that frequency markers always should appear on the oscilloscope screen irrespective of the settings of the klystron and receiver frequencies provided only that the klystron is swept over a range covering at least 10 MHz. The multiplier and mixer circuits may therefore be tuned up without searching for markers which otherwise may be a tedious business if the tuning is in some respect critical.

Rather than to increase the spacing between the standard frequencies it was therefore undertaken to increase the accuracy of the coarse measurements. For this purpose a variable frequency oscillator (VFO) was added to the frequency standard. In combination with a crystal calibrator this VFO may be used to measure the line frequencies to better than ± 2 MHz. The procedure employed is to produce

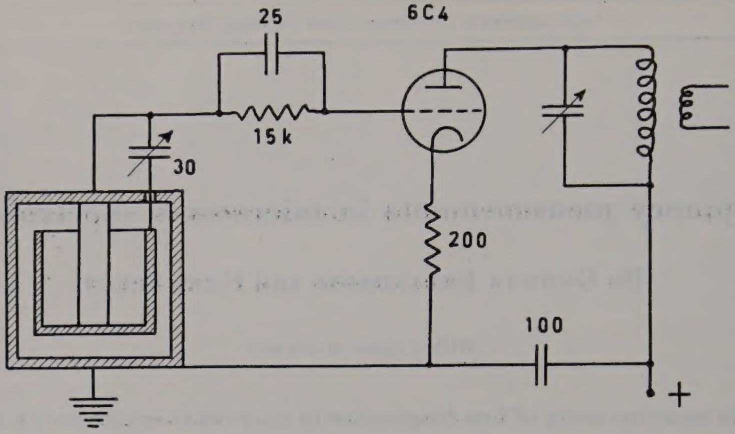

Fig. 1.

a variable set of reference frequencies in the region of the klystron frequency. This reference set is then used in the same manner as the standard frequencies.

The VFO is tunable between 148 and 152 MHz. It may be set to a zero beat against the crystal calibrator (Measurements, Model 111-B) at every 0.1 MHz. Within the tuning range it is always possible to find two settings f_1 and f_2 such that

$$nf_1 + \Delta f_1 = (n+1) f_2 + \Delta f_2 = \nu,$$

where ν is the spectrum line frequency, Δf_1 and Δf_2 are the measured differences both smaller than 30 MHz, counted positive or negative as the case may be. From these equations n is obtained as

$$n = \frac{f_2 + \Delta f_2 - \Delta f_1}{f_1 - f_2}.$$

The difference $f_1 - f_2$ is in the order of 1 MHz and the uncertainty therein can easily be kept smaller than 1000 Hz or 0.1%. The uncertainty in the numerator mainly comes from the Δf's which can be measured to better than ± 0.1 MHz. Thus the numerator is also known to about 0.1%, and therefore n is determined with at most 0.2% uncertainty. Since n must be an integer in the order of 100 its true value is then unambiguously determined. Inserting this value one gets ν with an accuracy determined by f_1 or f_2.

The accuracy of the crystal calibrator is about 1 part in 10^5 giving 1500 Hz at the VFO frequency. The beat note may be kept small compared to this value, and the ultimate accuracy of the measurement is thus about 1 part in 10^5 or ± 2 MHz. In practical tests the errors seldom have been found to exceed 1 MHz.

The VFO (Fig. 1) is a tuned plate-tuned grid oscillator with a pot-type tank circuit for the grid. A small variable capacitor across the pot provides the tuning possibility. The plate circuit is tuned to a fixed frequency slightly above 154 MHz and thus provides an inductive load over the tuning range.

The output from the VFO is fed into the last tripler of the frequency standard described previously [1]. The other multiplier stages of the standard are turned off, when the VFO is used. The tuned circuits of the tripler are kept fixed at 150 and 450 MHz respectively. As a consequence the output power drops to about 50% of its maximum value at the ends of the range. It is, however, still sufficient for driving the final crystal multiplier.

As mentioned above the main advantage of the VFO system over the cavity wavemeters is the increased accuracy. This allows keeping a small spacing between the standard frequencies thereby simplifying the interpolation measurements as well as the adjustment of the microwave system. An additional advantage is that the same apparatus is used for the entire frequency region of the spectrometer (12.5–25 kMHz). Changing from coarse to fine measurements is simply done by turning a switch.

The practical experience obtained with this arrangement shows that it is quite as convenient to use as the wavemeters. The latter are now used only for rapid localization of the klystron frequency, when no accuracy is required.

The substitution of a variable frequency oscillator for the cavity wavemeters was suggested by Dr. B. Bak, Copenhagen, at the Instruments and Measurements Conference in Stockholm 1951.

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REFERENCE

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